

# VARIABLE DIRECTIVITY ANTENNA AND VARIABLE DIRECTIVITY ANTENNA SYSTEM USING SUCH ANTENNAS

[0001] This invention relates to a variable directivity antenna and a  
5 variable directivity antenna system using such antennas.

## BACKGROUND OF THE INVENTION

[0002] A directional antenna may be used to receive a radio wave from a particular direction better than waves from other directions. A Yagi antenna is well-known as a directional antenna. A variable directivity antenna is used to  
10 selectively receive a desired one of radio waves from various directions. An example of variable directivity antenna is disclosed in Japanese Utility Model Publication No. SHO 63-38574 Y2 published on October 12, 1988.

[0003] The variable directivity antenna disclosed in this Japanese UM publication includes first and second antennas which lie to orthogonally  
15 intersect with each other in the same horizontal plane. Dipole antennas or folded dipole antennas are used as the first and second antennas. A signal received by the first antenna is applied through a first variable attenuator to a combiner, and a signal received by the second antenna is applied through a second variable attenuator to the combiner. The directivity of the variable  
20 directivity antenna can be varied by adjusting the amounts of attenuation provided by the first and second variable attenuators.

[0004] A Yagi antenna can receive better a radio wave from a fixed, particular direction, but it cannot receive well radio waves from other directions. The above-described variable directivity antenna has directivity that can rotate, and, therefore, it can receive only a radio wave from a desired direction  
25 selected from radio waves from various directions. However, the variable directivity antenna of Japanese Utility Model Publication No. SHO 63-38574 Y2 has a "8"-shaped directivity pattern, and, therefore, the antenna receives also a radio wave from the direction opposite to the desired direction. In other words,  
30 the antenna of Japanese Utility Model Publication No. SHO 63-38574 Y2 has a

low F/B ratio.

**[0005]** An object of the present invention is to provide a small-sized antenna that has an improved F/B ratio and can selectively receive well radio waves from different two directions. Another object of the present invention is to provide an antenna system that can selectively receive well desired ones of radio waves from various directions, by the use of the variable directivity antennas.

#### SUMMARY OF THE INVENTION

**[0006]** According to one embodiment of the present invention, an antenna has at least two antenna elements. The antenna elements are disposed generally in parallel with each other, being spaced from each other by a distance shorter than a quarter ( $1/4$ ) of the wavelength being employed. Each of the antenna element exhibits a 8-shaped directivity pattern. The antenna elements may be, for example, dipole antennas or folded dipole antennas. The two antenna elements are coupled to combining means by feeders having different lengths. The difference in length between the feeders is such that signals resulting from a radio wave coming from a second direction, which is generally perpendicular to the length direction of the antenna elements and opposite to a first direction, as received by the two antenna elements are opposite in phase at the inputs of the combining means. Variable phase means is connected between one of the at least two antenna elements and the combining means. The variable phase means can selectively assume first and second states. In the first state, a signal from the one antenna element is coupled to the combining means without being modified, and in the second state, the phase of the signal from the one antenna element is inverted before it is coupled to the combining means.

**[0007]** Now, let the antenna of the above-described arrangement be studied, ignoring the variable phase means. Received signals resulting from receiving a radio wave from the first direction by the first and second antenna elements are combined in the combining means. Received signals resulting

from receiving a radio wave from the second direction by the first and second antenna elements have their phases inverted substantially by  $180^\circ$  at the input of the combining means before being combined, and, therefore, the signals resulting from the wave from the second direction received by the first and second antenna elements are cancelled out. Thus, this antenna can have an improved F/B ratio. Since the distance between at least the two antenna elements is shorter than a quarter of the wavelength of the waves employed, the antenna as a whole can be small in size. By placing the variable phase means in the first state, the antenna receives almost no radio waves from the second direction. When the variable phase means is placed in the second state, the phases of the signals resulting from the radio wave from the first direction received by the first and second antenna elements are opposite in the input of the combining means, and, therefore, the antenna receives almost no radio wave from the first direction. Thus, by selecting the first and second states of the variable phase means, the antenna can be placed in states in which it receives almost no radio waves from selected ones of the first and second directions.

**[0008]** The received signals from the at least two antenna elements may be amplified by associated amplifying means, and the output signals from the amplifying means are fed to the associated feeders.

**[0009]** Since the received signals from the respective antenna elements are combined after being amplified, the antenna can have an improved C/N ratio.

**[0010]** The at least two antenna elements can be formed on a single printed circuit board. Then, the resulting antenna elements can be small in size. In this case, the antenna elements can be formed by etching.

**[0011]** The at least two antenna elements may be dipole antennas having their entire lengths so determined as to be able to receive radio waves in a first frequency band. Outward of the opposite ends of each dipole antenna, extension elements are disposed in line with the dipole antenna. The total

length of one dipole antenna and its extension elements disposed outward of the opposite ends of that dipole element is determined such as to be able to receive radio waves in a second frequency band lower than the first frequency band. The total length of the other dipole antenna and its extension elements  
5 disposed outward of the opposite ends of that dipole element is determined such as to be able to receive radio waves in the second frequency band. Switching means is connected between the one dipole antenna element and each of its outward extension elements, and also switching means is connected between the other dipole antenna element and each of its outward extension  
10 elements. Each of the switching means may be a semiconductor switching device that can pass and interrupt a high-frequency signal. Control signals for rendering the semiconductor switching devices conductive and nonconductive may be supplied from switching control means.

**[0012]** When the antenna with the above-described arrangement is to be  
15 used in, for example, the first frequency band, the switching means are opened so that only the dipole antenna elements can be used. If it is desired to use the antenna to receive radio waves in the second frequency band, the switching means are all closed so that the extension elements are connected to the associated dipole antenna elements. In this way, radio waves in the first and  
20 second different frequency bands can be received well.

**[0013]** An antenna system according to the present invention includes first and second antennas each configured as described above. The first and second antennas are disposed to generally orthogonally cross each other. Another antenna of the above-described configuration may be used in addition  
25 to the first and second antennas. A level adjusting arrangement includes first level adjusting means to which a received signal from the first antenna is coupled, and a second level adjusting means to which a received signal from the second antenna is coupled. The first level adjusting means adjusts the level of the received signal from the first antenna, before outputting it, in  
30 accordance with a first level control signal, while the second level adjusting

means adjusts the level of the received signal from the second antenna, before outputting it, in accordance with a second level control signal. The combining means operates to combine the output signals of at least the first and second level adjusting means. Level control signal generating means generates the  
5 first and second level control signals. The first level control signal varies along a sine waveform in a first varying range from zero through a first predetermined value back to zero, and the second level control signal varies along a cosine waveform in a second varying range from the first predetermine value through zero to a second predetermined value that is equal to the first  
10 predetermined value but of opposite sign. The second level control signal varies in synchronization with the first level control signal.

**[0014]** Each of the first and second antennas can receive a radio wave well from a particular direction, and the two antennas are arranged such that their "particular" directions can be orthogonal. The received signals from the  
15 first and second antennas are adjusted in level by the first and second level adjusting means in such a manner that the absolute value of the combination of the received signals can be always constant and the phase can vary within a range between, for example, 0 and 180 degrees. Accordingly, any desired one of radio waves from various directions can be received well.

**[0015]** Variable filter means may be added. The variable filter means includes a first variable filter that receives the received signal from the first antenna and has a passband variable in response to a first passband varying signal, and a second variable filter that receives the received signal from the second antenna and has a passband variable in response to a second passband  
25 varying signal. A low-pass filter or high-pass filter with a variable cutoff frequency may be used as each of the first and second variable filters. Alternatively, a bandpass filter having a passband with variable higher and lower limit frequencies may be used. Passband varying signal generating means provides the first and second passband varying signals to the first and  
30 second variable filters so that a desired radio wave can pass through the first

and second variable filters.

**[0016]** With the variable filter means, only a desired radio wave from one direction can be extracted by the first and second variable filters, and the extracted waves therefrom are combined. Accordingly, radio waves at other  
5 frequencies from the same direction can be rejected and give no adverse effects.

**[0017]** The passband varying signal generating means may be arranged to provide such first and second passband varying signals as to cause the first and second variable filters to pass a desired radio wave therethrough when the  
10 level control signal generating means are generating such first and second level control signals as to orient the directivity of the antenna system to the direction of the desired radio wave.

**[0018]** With such arrangement, the directivity of the antenna system can be aligned with the direction of the desired radio wave, and, at the same time,  
15 the desired radio wave is extracted by the variable filter means.

**[0019]** A receiving apparatus may be provided, to which the received signal is coupled from the antenna system through a transmission path. The receiving apparatus provides, through the transmission path, the antenna system with a command that causes the level control signal generating means  
20 to generate the first and second level control signals having desired values and to cause the passband varying signal generating means to generate the first and second passband varying signals. With this arrangement, the directivity adjustment and the receiving frequency adjustment in the antenna system can be done simultaneously by sending the command to the antenna system from  
25 the receiving apparatus.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0020]** FIGURE 1 is a plan view of a variable directivity antenna according to a first embodiment of the present invention.

**[0021]** FIGURE 2 is a circuit diagram of part of the antenna shown in  
30 FIGURE 1.

[0022] FIGURE 3 shows a horizontal directivity pattern of the antenna of FIGURE 1.

[0023] FIGURE 4 shows F/B ratio versus frequency and half-width versus frequency characteristics of the antenna of FIGURE 1.

5 [0024] FIGURE 5 shows a C/N ratio versus frequency characteristic of the antenna of FIGURE 1.

[0025] FIGURE 6 schematically shows the arrangement of a variable directivity antenna according to a second embodiment of the present invention.

[0026] FIGURE 7 is a block circuit diagram of a receiving system  
10 employing a variable directivity antenna system according to a third embodiment of the present invention.

[0027] FIGURE 8 is a block circuit diagram of the variable directivity antenna system of the third embodiment used in the receiving system of FIGURE 7.

15 [0028] FIGURE 9 shows changes of two factors used in a variable attenuator in the antenna system of FIGURE 8.

[0029] FIGURES 10A, 10B, 10C, 10D, 10E, and 10F show changes of the directivity of the antenna system of FIGURE 8.

[0030] FIGURE 11 is a block diagram of a receiving apparatus in the  
20 receiving system of FIGURE 7.

[0031] FIGURE 12 shows part of a flow chart for use in explaining how antenna directivities are stored in a memory in a tuner of the receiving apparatus of FIGURE 11.

[0032] FIGURE 13 shows the remainder of the flow chart for use in  
25 explaining how antenna directivities are stored in a memory in a tuner of the receiving apparatus of FIGURE 11.

[0033] FIGURE 14 shows part of a flow chart for use in explaining the processing performed in the tuner of the receiving apparatus of FIGURE 11 when the antenna directivity deviates from an acceptable state.

30 [0034] FIGURE 15 shows the remainder of the flow chart for use in

explaining the processing performed in the tuner of the receiving apparatus of FIGURE 11 when the antenna directivity deviates from an acceptable state.

**[0035]** FIGURE 16 is a block diagram of a modification of the antenna shown in FIGURE 1.

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## EMBODIMENTS

**[0036]** A variable directivity antenna 1 according to a first embodiment of the present invention may be used to receive a radio wave in a first frequency band, e.g. in the UHF band (470-890 MHz) used for television broadcasting. As shown in FIGURE 1, the antenna 1 has plural, e.g. two, antenna elements 2 and 4. The antenna elements 2 and 4 are folded dipole antennas of which the entire length is, for example, about 20 cm that is equal to about one-half of the wavelength  $\lambda$  at the center frequency, 620 MHz, of the UHF band. The two antenna elements 2 and 4 are disposed in parallel with each other with a predetermined distance  $d$  disposed therebetween. The distance  $d$  may be, for example, 20 mm, that is equal to about  $\lambda/20$ . The antenna elements 2 and 4 are planar type elements that are formed by etching a metal film on a printed circuit board 6.

**[0037]** Feeding points 2a and 2b disposed in the center portion of the antenna element 2 are coupled to a matching device, for example, a balun 8. Similarly, feeding points 4a and 4b in the center portion of the antenna element 4 are coupled to a balun 10. The baluns 8 and 10 may be formed on the printed circuit board 6, too, together with the antenna elements 2 and 4. The outputs of the baluns 8 and 10 are amplified in amplifiers 11 and 13, respectively. The amplifiers 11 and 13 may be formed on the printed circuit board 6, too. The outputs of the amplifiers 11 and 13 are coupled through feeders 12 and 14 to inputs 16a and 16b, respectively, of combining means, e.g. a combiner 16. Combining the signals from the antenna elements 2 and 4 after they are amplified by the amplifiers 11 and 13, provides a better C/N ratio than amplifying the combiner output. The lengths of the feeders 12 and 14 are different from each other. For example, the feeder 12 may have a length



of  $L + \Delta L$ , whereas the feeder 14 may have a length of  $L$ . In other words, the feeder 12 has a length larger by  $\Delta L$  than the feeder 14.

**[0038]** The value  $\Delta L$  is determined in the following way. Let it be assumed that the side of the antenna 1 on which the antenna element 2 is disposed is the front side, and the side of the antenna 1 on which the antenna element 4 is disposed is the back side. A radio wave coming from a second direction, i.e. coming from the back, in parallel with the surface of the printed circuit board 6 and perpendicularly to the length direction of the antenna elements 2 and 4, is received by the antenna elements 2 and 4 and propagates through the feeders 12 and 14 to the inputs 16a and 16b of the combiner 16, respectively. The signal resulting from the radio wave from the second direction as received by the antenna element 2 has its phase delayed from the signal resulting from the same radio wave as received by the antenna element 4, by an amount corresponding to the distance  $d$  between the antenna elements 2 and 4, and reaches the input 16a of the combiner 16, being delayed by an amount corresponding to  $\Delta L$ , the difference in length between the feeders 12 and 14. In other words, the signal based on the radio wave from the second direction received by the antenna element 2 has its phase delayed from the signal based on the same radio wave received by the antenna element 4, by an amount corresponding to  $\Delta L + d$ , when they reach the inputs 16a and 16b of the combiner 16, respectively. The value  $\Delta L$  is determined such that the two signals at the inputs of the combiner 16 are opposite in phase.

**[0039]** A radio wave coming from a first direction, i.e. coming from the front, in parallel with the surface of the printed circuit board 6 and perpendicularly to the length direction of the antenna elements 2 and 4, is received by the antenna elements 2 and 4 and propagates through the feeders 12 and 14 to the inputs 16a and 16b of the combiner 16, respectively. The signal resulting from the radio wave from the first direction as received by the antenna element 4 has its phase delayed from the signal resulting from the same radio wave from the first direction as received by the antenna element 2,

by the amount corresponding to the distance  $\underline{d}$  between the antenna elements 2 and 4. The delay is reduced by  $\Delta L$ .

**[0040]** For example,  $\Delta L$  is determined such as to provide a delay corresponding to about  $0.37\lambda$ . Then, although the radio wave from the first direction or front received by the antenna element 4 has a phase difference of  $+\lambda/20$  ( $= 0.05\lambda$ ) relative to the same radio wave from the front received by the antenna element 2, the signals from the antennas 2 and 4 resulting from that radio wave are combined with a phase difference equal to  $0.32\lambda$  ( $= 0.37\lambda - 0.05\lambda$ ) because they propagate through the feeders 12 and 14 before reaching the inputs 16a and 16b of the combiner 16. Also, the radio wave from the second direction or back received by the antenna element 4 has a phase difference of  $-0.05\lambda$  relative to the same radio wave from the back received by the antenna element 2. The signal from the antenna element 2 is provided with a delay of  $-0.37\lambda$  when it is transmitted through the feeder 12, and exhibits a phase difference of  $-0.42\lambda$  ( $= -0.05\lambda - 0.37\lambda$ ) relative to the signal from the antenna element 4 at the input 16a of the combiner 16. This phase difference is approximately  $\lambda/2$ , and, therefore, the signal from the back of the antenna 1 is substantially cancelled.

**[0041]** Then, the signals resulting from the radio wave from the front of the antenna 1 received by the antenna elements 2 and 4 are combined with a reduced phase difference, whereas the signals resulting from the radio wave from the back received by the antenna elements 2 and 4 are combined, being substantially oppositely phased. As a result, the antenna 1 operates as a directional antenna with no backward main lobe. Generally, if the lengths of the feeders from the antenna elements 2 and 4 to the combiner 16 are equal, the distance  $\underline{d}$  between the antenna elements 2 and 4 must be  $\lambda/4$  in order to couple signals resulting from a radio wave from the front as received by the antenna elements 2 and 4, in phase with each other to the inputs 16a and 16b of the combiner 16, and to couple signals resulting from a radio wave from the back as received by the antenna elements 2 and 4, in opposite phase to the

inputs 16a and 16b of the combiner 16. Such larger distance  $d$  of  $\lambda/4$  makes the antenna larger. In contrast, according to the first embodiment of the present invention, the distance  $d$  between the antenna elements 2 and 4 can be smaller, e.g.  $\lambda/20$ , than  $\lambda/4$  because the difference of  $\Delta L$  is provided between the length of the feeder 12 and the length of the feeder 14, and, therefore, the size of the antenna 1 can be smaller.

**[0042]** FIGURE 3 shows a horizontal directivity pattern of the antenna 1 at 470 MHz. As is understood from this pattern, the antenna 1 exhibits a large F/B ratio of, for example, 8.1 dB and, therefore, can receive radio waves from the front of the antenna 1 better than radio waves from the back. Also, the antenna 1 exhibits a half-width at about  $82^\circ$ . FIGURE 4 shows the F/B ratio versus frequency characteristic of the antenna 1 and also the half-width versus frequency characteristic. The solid line is for the F/B ratio, and the broken line is for the half-width. As is seen, the F/B ratio is within a range of from about 7.5 dB to about 11 dB, which is sufficiently practically usable in the entire UHF band. Also, the half-width is within a range of from about  $68^\circ$  to about  $82^\circ$ , which is also practically useable in the entire UHF band. FIGURE 5 shows the C/N ratio versus frequency characteristic of the antenna 1 relative to the antenna 1 with the amplifiers 11 and 13 removed. As is seen from FIGURE 5, the use of the amplifiers 11 and 13 improves the C/N ratio by about 2.8 dB at the worst. The highest frequency of the UHF band shown in FIGURES 4 and 5 is about 800 MHz. In U.S.A., however, the highest frequency of the UHF band actually utilized is 806 MHz, and, therefore, FIGURES 4 and 5 clearly show that the antenna 1 is useful in receiving radio waves in the UHF band in U.S.A.

**[0043]** The antenna 1 with the above-described arrangement is adapted to receive well only a radio wave coming from the front side of the antenna 1. However, it may become necessary for the antenna 1 to receive a radio wave coming thereto from the back. For that purpose, variable phase means, for example, a variable phase device 18 is connected to the input 16b of the

combiner 16 as shown in FIGURE 2. The variable phase device 18 can selectively assume a state in which it can couple the signal resulting from a radio wave received by the antenna element 4 and transmitted through the feeder 14 to the input 16b of the combiner 16 without modifying it, and a state  
5 in which it couples the signal to the input 16b after phase-shifting it by  $180^\circ$ . The  $180^\circ$  phase inverted version of the signal resulting from the radio wave from the front received by the antenna element 4 and transmitted through the feeder 14 can be combined with the signal of substantially opposite phase resulting from the same radio wave received by the antenna element 2 and  
10 transmitted through the feeder 12. The  $180^\circ$  phase inverted version of the signal resulting from the radio wave from the back of the antenna 1 received by the antenna element 4 and transmitted through the feeder 14 is combined with the signal resulting from the same radio wave from the back received by the antenna element 2 and transmitted through the feeder 12. Accordingly, the  
15 antenna 1 exhibits a backward directivity.

**[0044]** The variable phase device 18 has selecting means, for example, a selector switch 20 that has contacts 20a and 20b. The switch 20 also has a contact element 20c that is selectively brought into contact with the contacts 20a and 20b. The contact element 20c is connected to the feeder 14, and the  
20 contact 20a is connected to the input 16b of the combiner 16. Connected between the contacts 20a and 20b is a delay element, e.g. a delay line 22 having such a length as to provide a delay of  $180^\circ$  for the signal at the above-stated center frequency. With the contact 20a contacted by the contact element 20c, the signal transmitted through the feeder 14 is coupled to the  
25 input 16b of the combiner 16 without being delayed. With the contact 20b contacted by the contact element 20c, the signal transmitted through the feeder 14 has its phase inverted by the delay line 22 before being coupled to the input 16b of the combiner 16. The selector switch 20 may be an electronic selector switch, e.g. a semiconductor switching device. The semiconductor switching  
30 device may be, for example, a PIN diode. With an electronic selector switch,

directivity switching can be remote controlled. The variable phase device 18 may be connected to the feeder 12 instead of the feeder 14. Further, the variable phase device 18 may be formed on the printed circuit board 6.

**[0045]** As described above, the antenna 1 exhibits directivity in selected one of the forward and backward directions, and can be small in size because it is formed on the printed circuit board 6.

**[0046]** The above-described antenna 1 is for receiving radio waves in the UHF band. An antenna 30 according to a second embodiment of the invention shown in FIGURE 6 is arranged to be able to receive radio waves in a second frequency band, e.g. VHF television broadcasting waves (at frequencies of 54-88 MHz and 174-216 MHz), in addition to waves in the UHF band. In order for the antenna 30 to be operable both in the UHF and VHF bands, dipole antennas are used as antenna elements 32 and 34. The antenna elements 32 and 34 have a length of about 250 mm, and are disposed in parallel with each other. The antenna elements 32 and 34 are spaced by a distance  $d$  of about 30 mm. Like the antenna 1 of the first embodiment, the antenna elements 32 and 34 are formed on a printed circuit board.

**[0047]** Outward of and close to the respective opposite outer ends of the antenna element 32, extension elements 36 and 38 are disposed in line with the antenna element 32. Similarly, extension elements 40 and 42 are disposed in line with the antenna element 34 outward of and close to the respective opposite outer ends of the antenna element 34. The extension elements 36, 38, 40 and 42 are also formed on the printed circuit board by etching metal layers on the board. The length of each of the extension elements 36, 38, 40 and 42 is about 100 mm. Accordingly, the sum in length of the antenna element 32 and its extension elements 36 and 38 is about 450 mm, and the sum in length of the antenna element 34 and its extension elements 40 and 42 is also about 450 mm.

**[0048]** Switching means, which may be semiconductor switching devices, e.g. PIN diodes 44 and 46, are connected between the outer ends of the

antenna element 32 and the extension elements 36 and 38, respectively. The PIN diodes 44 and 46 have their anodes connected to the antenna element 32 and have their cathodes connected respectively to the extension elements 36 and 38. Similarly, PIN diodes 48 and 50 are connected between the outer  
5 ends of the antenna element 34 and the extension elements 40 and 42, respectively. The PIN diodes 44 and 46 have their anodes connected to the antenna element 34 and have their cathodes connected respectively to the extension elements 40 and 42. With the PIN diodes 44, 46, 48 and 50 being conductive, the antenna element 32 is connected to the extension elements 36  
10 and 38, and the antenna element 34 is connected to the extension elements 40 and 42, so that the antenna elements 32 and 34 with their extension elements can operate as VHF antennas. With the PIN diodes 44, 46, 48 and 50 rendered nonconductive, only the antenna elements 32 and 34 operate and act as UHF antennas.

15 **[0049]** In order to render the PIN diodes 44, 46, 48 and 50 conductive and nonconductive, the extension elements 36, 38, 40 and 42 are connected to a point of reference potential, e.g. a point of ground potential, via respective current supply paths, e.g. high-frequency blocking coils 52, 54, 56 and 58. In order to cause DC current to flow from the antenna element 32 through the PIN  
20 diodes 44 and 46 and the high-frequency blocking coils 52 and 54, a switch 64 and a DC supply 68 are connected to a balun 60 to which central feed points of the antenna element 32 are connected. Similarly, in order to cause DC current to flow from the antenna element 34 through the PIN diodes 48 and 50 and the high-frequency blocking coils 56 and 58, a switch 66 and a DC supply  
25 70 are connected to a balun 62 to which central feed points of the antenna element 34 are connected. Instead of using the DC supplies 68 and 70 in association with the switches 64 and 66, respectively, a single DC supply may be connected to the switches 64 and 66.

**[0050]** The baluns 60 and 62 have the same configuration, and, therefore,  
30 only the balun 62 is described in detail. Respective one ends of inductors 72

and 74 are connected to the two feeding points of the antenna element 34. The other end of the inductor 72 is grounded via a capacitor 76, and the other end of the inductor 74 is connected to an output terminal 78 of the balun 62. An inductor 80 is disposed with respect to the inductor 72 in such a way that they are inductively coupled with each other, and an inductor 82 is disposed with respect to the inductor 74 in such a way that they are inductively coupled with each other. The inductors 80 and 82 have their one ends interconnected, with the other end of the inductor 80 connected to the other end of the inductor 74, and with the other end of the inductor 82 connected to the other end of the inductor 72. A series combination of the switch 66 and the DC supply 70 is connected via a low-pass filter 84 to the junction of the inductors 74 and 80. The low-pass filter 84 includes a high-frequency blocking coil 84a and a capacitor 84b.

**[0051]** With the switch 66 closed, current from the DC supply 70 flows through the inductor 74, the antenna element 34 and the PIN diode 50 to the high-frequency blocking coil 58, and also flows through the inductors 80, 82 and 72, the antenna element 34, and the PIN diode 48 to the high-frequency blocking diode 56. This renders the PIN diodes 48 and 50 conductive for receiving the UHF band. If the switch 66 is opened, no DC current flows from the DC supply 70, rendering the PIN diodes 48 and 50 nonconductive, for receiving the UHF band.

**[0052]** Similarly, by opening or closing the switch 64 associated with the balun 60, the UHF or VHF band reception mode can be selected. It is desirable to operate the switches 64 and 66 in synchronization with each other. By using semiconductor switching devices as the switches 64 and 66, and supplying external switching control signals to the switches 64 and 66, remote control is possible.

**[0053]** The remainder of the antenna 30 is similar to the antenna 1 of FIGURE 1, the same reference numerals and symbols as used in FIGURE 1 are used for the same or similar components, and their detailed description is not

made. It should be noted, however, that a variable phase device 18a is used in place of the variable phase device 18. The variable phase device 18a includes two variable devices 18b and 18c for the reception of the VHF and UHF bands which are selectively used, being selected by a switch 18d. When  
5 the switches 64 and 66 are open, the variable phase device 18b for the UHF band is used, while the variable phase device 18c for the VHF band is used when the switches 64 and 66 are closed. By using a semiconductor switching device as the switch 18d, remote control of the variable phase device 18a is possible.

10 **[0054]** The above-described arrangement makes it possible to selectively receive radio waves in the UHF and VHF bands coming to the antenna 30 from the front and back thereof.

**[0055]** A variable directivity antenna system 90 according to a third embodiment of the invention is shown in FIGURES 7 through 11. The variable  
15 directivity antenna system 90 includes an antenna set formed of antennas 30a and 30b of the same configuration as the antenna 30 according to the second embodiment shown in FIGURE 6. The antenna system 90 can receive well any desired one of UHF and VHF radio waves coming from various directions.

**[0056]** The antenna system 90 receives, at its input terminal 90a, a  
20 satellite broadcast intermediate-frequency signal resulting from a satellite broadcast signal received by a satellite broadcast receiving antenna, e.g. a satellite broadcast receiving parabolic antenna 92, and frequency-converting in a converter 94 provided in association with the parabolic antenna 92. The satellite broadcast intermediate-frequency signal is mixed with a UHF or VHF  
25 band television broadcast signal received by the antenna system 90, and the mixture signal is outputted from an output terminal 90b of the antenna system 90. The mixture signal at the output terminal 90b is coupled through a transmission line 96 to a splitter 98 where the mixture signal is split into the satellite broadcast intermediate-frequency signal and the VHF or UHF band  
30 television broadcast signal. The satellite broadcast intermediate-frequency



signal is coupled to a satellite broadcast intermediate-frequency signal input terminal 100a of a receiving apparatus 100, and the VHF or UHF band television broadcast signal is coupled to a VHF/UHF band television broadcast signal input terminal 100b.

5   **[0057]**       The antennas 30a and 30b of the antenna system 90 are disposed to orthogonally intersect with each other as shown in FIGURE 8. The antenna elements 30a and 30b are formed on separate printed circuit boards by etching and are disposed at different levels so as to be orthogonal with each other at their feeding points. The antenna elements 30a and 30b may be formed on a  
10   single printed circuit board.

**[0058]**       Signals from the antenna elements 30a and 30b are coupled to variable filter means, e.g. variable filters 102 and 104. The variable filters 102 and 104 are bandpass filters having variable passbands. The passband of each filter 102, 104 is varied in response to a passband varying signal  
15   supplied by passband varying control means, e.g. a control unit 106. The passbands are varied so that the frequencies of the radio waves to be received by the antenna system 90 can lie in the passbands. In place of the bandpass filters, variable cutoff frequency high-pass or low-pass filters may be used. The cutoff frequencies of such high-pass or low-pass filters are so varied that  
20   the frequencies of the waves to be received can be within the passbands of the filters.

**[0059]**       Output signals of the variable filters 102 and 104 are amplified in amplifiers 108 and 110, respectively, and coupled to level adjusting means, e.g. variable attenuators 112 and 114, respectively. The variable attenuators 112  
25   and 114 may include a semiconductor device, e.g. a PIN diode, having its conductivity varied in response to a respective level control signal supplied to it from level control signal generating means, which may be the control unit 106. Variable gain amplifiers may be used in place of the variable attenuators 112 and 114.

30   **[0060]**       The output of the variable attenuator 112 is the output signal from

the amplifier 108 multiplied by a factor K1, and the output of the variable attenuator 114 is the output signal from the amplifier 110 multiplied by a factor K2. The factor K1 is variable in response to the level control signal for the variable attenuator 112, and the factor K2 is variable in response to the level control signal for the variable attenuator 114. As shown in FIGURE 9, the level control signal for the variable attenuator 112 varies the factor K1 from a first value, e.g. 1, through 0 to a second value, e.g. -1, which is equal in absolute value but has an opposite sign to the first value. The variation is in a cosine waveform fashion. The level control signal for the variable attenuator 114 varies the factor K2 from zero through the first value, e.g. 1, back to 0. The variation of the factor K2 is sinusoidal and in synchronization with the factor K1. Accordingly, the value of  $K1^2 + K2^2$  is always the first value, e.g. 1. The value of the sum,  $K1^2 + K2^2$ , can be other than 1, as shown in FIGURE 9, as long as the factors K1 and K2 change in the above-described synchronized, sine and cosine waveform fashions.

**[0061]** The control unit 106 provides the antennas 30a and 30b with frequency-band switching signals for switching the antenna 30a and 30b between the UHF receiving mode and the VHF receiving mode, i.e. selectively opening and closing the switches 64 and 66 shown in FIGURE 6, and for switching the switch 18d of the variable phase device 18a. Also, the control unit 106 provides the antennas 30a and 30b with a directivity inverting signal for inverting the phase of signals by 180° in the variable phase devices 18b and 18c.

**[0062]** Output signals of the variable attenuators 112 and 114 are combined with each other in combining means, e.g. a combiner 116. Thus, the directivity of the combined signal of the antennas 30a and 30b as combined in the combiner 116 can be varied to any desired direction by changing the factors K1 and K2, as is well known. Let it be assumed that the phase shifters 18b and 18c are so adjusted to provide, for example, the antenna 30a with the upward directivity in the plane of the sheet of FIGURE 8, and the antenna 30b

with the leftward directivity. In this state, if the factor K1 for the variable attenuator 112 is 1 and the factor K2 for the variable attenuator 114 is 0, the directivity of the signal at the output of the combiner 116 is as shown in FIGURE 10A. When the factor K1 is  $\cos 30^\circ$  with the factor K2 being  $\sin 30^\circ$ ,  
5 the directivity rotates by  $30^\circ$  from the one shown in FIGURE 10A to the one shown in FIGURE 10B. With the factors K1 and K2 being  $\cos 45^\circ$  and  $\sin 45^\circ$ , respectively, the directivity rotates by  $45^\circ$  from the one shown in FIGURE 10A to the one shown in FIGURE 10C. With the factors K1 and K2 being  $\cos 60^\circ$  and  $\sin 60^\circ$ , respectively, the directivity rotates by  $60^\circ$  from the one shown in  
10 FIGURE 10A to the one shown in FIGURE 10D. With the factors K1 and K2 being  $\cos 90^\circ$  and  $\sin 90^\circ$ , respectively, the directivity rotates by  $90^\circ$  from the one shown in FIGURE 10A to the one shown in FIGURE 10E. Similarly, when the factor K1 is changed to  $\cos 180^\circ$  with the factor K2 changed to  $\sin 180^\circ$ , the directivity changes from the one shown in FIGURE 10E to the one shown in  
15 FIGURE 10F. By properly selecting the values of the factors K1 and K2, the directivity can be changed to any one lying between adjacent ones shown in FIGURES 10A-10F. To change the directivity from the one shown in FIGURE 10F to any desired one between the directivities shown in FIGURES 10F and 10A, the variable phase devices 18b and 18c associated with the antennas 30a  
20 and 30b are adjusted to invert, by  $180^\circ$ , the directivities inherent to the antennas 30a and 30b, and, then, the factors K1 and K2 are changed in a manner similar to the one described above.

**[0063]** As described above, since the directivity of the antenna system 90 can be changed to any direction, it can receive well any desired one of radio  
25 waves from various directions. The control unit 106 controls the passbands of the variable filters 102 and 104 to pass therethrough the desired radio wave when it is being received by the antenna system 90, whereby the antenna system 90 is prevented from receiving undesired radio waves, which can improve a D/U ratio.

30 **[0064]** An output signal from the combiner 116 is amplified by an amplifier

118 and, then, coupled through a DC blocking capacitor 120 to a mixer 122. The mixer 122 receives also the satellite broadcast intermediate-frequency signal from the input terminal 90a of the antenna system 90. The output signal of the combiner 116 and the satellite broadcast intermediate-frequency signal are mixed with each other in the mixer 122, and the mixture signal developed at the output terminal 90b of the antenna system 90 is coupled via the transmission line 96 to the splitter 98 where the output signal of the mixer 116 and the satellite broadcast intermediate-frequency signal are separated for application to the satellite broadcast intermediate-frequency signal input terminal 100a of the receiving apparatus 100, and to the television broadcast signal input terminal 100b, as described previously.

**[0065]** A television broadcast signal processing unit of the receiving apparatus 100 includes, as shown in FIGURE 11, a tuner 126 to which the television broadcast signal, i.e. the output signal of the mixer 116, is coupled through a DC blocking block 124, and the tuner 126 demodulates the received television broadcast signal. The receiver 100 includes a power supply unit, e.g. a DC power supply unit 128, for driving the antenna system 90. A DC voltage from the DC power supply unit 128 is coupled through the input terminal 100b, the splitter 98, the transmission line 96, the output terminal 90b of the antenna system 90, and the mixer 122 to a DC power supply unit 130 (FIGURE 8). The DC power supply unit 130 regulates the voltage for application to various sections. The DC power supply unit 130 supplies DC power to the PIN diodes of the antenna 30a and 30b.

**[0066]** The receiving apparatus 100 includes also memory means, e.g. a memory 131. The memory 131 stores therein antenna control data necessary for the antenna system 90 to receive desired radio waves (e.g. a television broadcast channel desired to be received). Such control data is stored, being correlated with corresponding channel data indicative of respective desired television broadcast channels, and indicates the receiving band to be received, i.e. the UHF or VHF band, the desired direction of directivity, the passbands of

the variable bandpass filters, and the phase conditions of the variable phase devices 18b and 18c. When the tuner 126 reads out channel data from the memory 131, the associated antenna control data is supplied to an antenna control commander 132. The antenna control commander 132 converts the antenna control data to an FSK signal or an ASK signal. The resulting FSK or ASK signal is applied to the control unit 106 through the input terminal 100b, the splitter 98, the transmission line 96, the output terminal 90b of the antenna system 90, and the mixer 122. When receiving the FSK or ASK signal, the control unit 106 demodulates the FSK or ASK signal to the antenna control data. In accordance with the demodulated antenna control data, the switches 66 and 68 of the antennas 30a and 30b are ON-OFF controlled, the passbands of the variable filters 102 and 104 are modified, and the factors K1 and K2 for the variable attenuators 112 and 114 are altered, and the variable phase devices 18b and 18c of the antennas 30a and 30b are set to provide in-phase or 180°-out-of-phase condition.

**[0067]** In order for such control to be provided, it is necessary to store the receiving channel data and the corresponding antenna control data in association with each other, in the memory 131. For that purpose, the processing as shown in FIGURES 12 and 13 is performed in the tuner 126. The tuner 126 can receive both analog television broadcast signals and digital television broadcast signals.

**[0068]** First, an automatic channel mode is selected (Step S2). This causes the channel designating value in a channel counter n to be set to an initial value. The channel counter n is for designating a channel to be received. Then, the value in the channel counter n is increased by one for designating a certain channel to be received (Step S4), whereby this channel is selected in the tuner 126, and, at the same time, data for making the variable filters 102 and 104 have passbands for receiving that channel is transmitted from the antenna control commander 132 to the control unit 106. Then, the tuner 126 makes a judgment as to whether the selected channel is an analog

television broadcast channel or not (Step S6).

**[0069]** If the selected channel is an analog television broadcast channel, a command is transmitted from the antenna control commander 132 to the control unit 106 to successively change K1 and K2 and also to adjust the variable phase devices 18b and 18c to provide the in-phase or 180°-out-of-phase condition, whereby the direction of directivity of the antenna is successively changed. The reception level for each direction is measured in the tuner 126 and stored (Step S8). In Step S10, whether the directivity of the antenna has been measured for all the predetermined directions in the angular range of 360° or not is judged. If it has not, the execution of Steps S8 and S10 is repeated in loop until the answer to the query in Step S10 becomes YES. When the answer to the query in Step S10 becomes YES, whether or not the largest one of the measured levels is at or above a predetermined reference level is examined (Step S12). In other words, whether or not there is directivity providing an acceptable receiving condition is judged. If the answer is YES, the direction of directivity providing the largest reception level is stored together with the largest reception level in the memory 131 (Step S14). At the same time, the data representing the passbands of the variable filters 102 and 104, and the data indicating which condition, in-phase or 180°-out-of-phase condition, the variable phase devices 18b and 18c provided, employed when the largest reception level has been attained, are stored in the memory 131 in association with the largest directivity providing direction and the largest reception level. After that, whether the value in the channel counter n is the value for the last one of the receiving channels is judged (Step S16). If the answer is NO, it means that there are channels left for which the direction of directivity has not yet been determined. Then, the processing is repeated from Step S4 until the answer to the query in Step S16 becomes YES.

**[0070]** The answer of NO to the query in Step S12 indicates that there is a possibility that no radio wave is broadcast in that channel. In this case, Step S4 is executed to designate the next receiving channel.

**[0071]** If the selected channel is judged to be a digital television broadcast channel in Step S6, as indicated by a circled A, the direction of directivity of the antenna system 90 is varied, and the bit error rate (BER) for each direction is measured and stored (Step S18), as shown in FIGURE 13. Then, whether the bit error rate has been measured and stored for all of the predetermined directions in the angular range of  $360^\circ$  is judged (Step S20). If the measurement and storage has not been completed, Steps S18 and S20 are repeated in loop until the answer in Step S20 changes to YES. When the answer to the query in Step S20 changes to YES, whether the smallest one of the measured bit error rates is equal to or smaller than a predetermined rate is judged (Step S22). That the smallest bit error rate is not greater than the predetermined rate means that the digital television broadcast signal can be received by the antenna system 90 with an allowable level, that direction of the antenna directivity and the smallest bit error rate are stored in the memory 131 (Step S24). At the same time, the data specifying the passbands of the variable filters 102 and 104, and the data indicating which condition, in-phase or  $180^\circ$ -out-of-phase condition, the variable phase devices 18b and 18c provide, employed when the allowable smallest bit error rate has been attained, are stored in the memory 131 in association with the direction of the antenna directivity in which the smallest bit error rate is measured and that smallest bit error rate. Thereafter, whether the value in the channel counter n is the value corresponding to the largest channel is seen (Step S26), and if the value is not for the largest channel, the steps are repeated from Step S4, as indicated by a circled B.

**[0072]** The answer of NO to the query in Step S22 may mean that no wave is broadcast in that channel, and, therefore, the processing is repeated from Step S4.

**[0073]** In this way, the storing in the memory 131 of the antenna control data necessary for the antenna system 90 to receive desired radio waves is completed.

**[0074]** It may occur that, while a radio wave of a certain television channel is being received by the tuner 126, a broadcast signal condition worsens to an unacceptable condition. In such a case, processing as shown in FIGURES 14 and 15 is executed for that television channel.

5 **[0075]** Referring to FIGURE 14, a desired channel to be received is selected and set (Step S28). Whether the desired channel is an analog television broadcast channel or a digital television broadcast channel is judged (Step S30). If the selected channel is an analog channel, the antenna control data relating to the direction of directivity for the desired channel is read out  
10 from the memory 131 and set (Step S32). Then, the reception signal level for the set directivity is measured (Step S34). The measured level is examined as to if it is equal to or higher than the reference level (Step S36). If the level is at or above the reference level, which means that the signal is being received in a good condition, the reception of the radio wave of the channel is continued,  
15 repeating Steps S34 and 36 in loop.

**[0076]** If it is judged, in Step S36, that the received signal level is lower than the reference level, the direction of antenna directivity is successively altered, and the signal level at each of the altered directions is measured and stored (Step S38). Then, whether the signal levels for all the predetermined  
20 directions in the 360° angular range have been measured and stored is judged (Step S40), and, if not, Steps S38 and S40 are repeated in loop until the answer to Step S40 becomes YES. When it is judged, in Step S40, that the signal levels at all of the predetermined directions have been measured and stored, the highest one of the measured signal levels is examined as to if it is equal to  
25 or above the reference level (Step S42). If the answer is YES, the direction in which the highest level is obtained and the reception level are stored in the memory 131 (Step S44). Then, the antenna directivity is set for that direction (Step S46), and the processing resumes from Step S34.

**[0077]** The answer of NO to the query in Step S42 may mean that the  
30 signal in the channel cannot be received in an allowable condition with any



directivities or the signal has disappeared. Accordingly, the reception of the signal in that channel is abandoned.

**[0078]** If the desired signal to be received is judged to be a digital television broadcast channel signal in Step S30, the processing shown in  
5 FIGURE 15 is executed, as indicated by a circled C in FIGURE 14. The antenna system is set for the antenna directivity for the channel set in Step S28, using the data read out from the memory 131 (Step S48). Then, the BER (bit error rate) for that directivity is measured (Step S50). Whether the measured BER is not greater than the reference value is examined (Step S52). The fact  
10 that the measured BER is equal to smaller than the reference value means that the signal of the set digital broadcast channel is being received at an allowable level, the reception is continued, and the execution of Steps S50 and S52 is iterated. If the answer to the query in Step S52 becomes NO, the antenna directivity is successively changed stepwise over a 360° angular range, and the  
15 BER for each directivity is stored (Step S54). Whether the antenna directivity has rotated 360° or not is judged (Step S56), and, if the answer is NO, the execution of Steps S54 and S56 is iterated until the answer changes to YES. When the answer to the query in Step S56 changes to YES, whether the smallest one of the stored values of BER is not greater than the reference BER  
20 value is examined (Step S58). If the answer is YES, the direction or directivity for which that smallest BER is obtained is stored together with that BER in the memory 131 (Step S60). The antenna directivity is adjusted to the stored direction (Step S62), and the processing is repeated from Step S50 again.

25 **[0079]** The answer of NO to the query in Step S58 may mean that the signal in the channel cannot be received in an allowable condition with any directivities or the signal has disappeared. Accordingly, the reception of the signal in that channel is abandoned.

**[0080]** The antenna 1 shown in FIGURE 1 is arranged such that the  
30 received signals from the antenna elements 2 and 4 are coupled in phase with

each other to the baluns 8 and 10, that the length of the feeder 12 is longer by  $\Delta L$  than the feeder 14 to provide a delay, and that the variable phase device 18 is used. Alternatively, as shown in FIGURE 16, the received signal from the antenna element 2 may be coupled to the balun 8 with a phase opposite to the phase of the received signal coupled from the antenna element 4 to the balun 10, with the feeder 14 longer by  $\Delta L$  than the feeder 12 used to provide a delay as represented by a delay element 150, and with the variable phase device 18 connected in the succeeding stage of the delay element 150. The same modification may be done to the variable directivity antenna according to the second embodiment shown in FIGURE 6.

**[0081]** The antenna system according to the third embodiment uses two antennas 30a and 30b, but the number is not limited to two, and a larger number of antennas may be used. Furthermore, instead of using dipole antennas as the antennas 30a and 30b, folded dipole antennas as used in the antenna 1 shown in FIGURE 1 may be employed.